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DISASTER RISK ASSESSMENT TECHNIQUE AND CASE STUDY FOR TAIWAN'S HERITAGES

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How to educate heritage managers and stakeholders to assess risks associated with their heritage using a simple method is an important issue in promoting disaster prevention disaster mechanism. Based on Taiwan heritages' vulnerability and preservation needs, this study developed a simple disaster risk assessment method. Using disaster risk assessment basis established both in Taiwan as well as internationally, a simple method is established allowing preservation specialists, heritage managers, and stakeholders to assess the heritage's risks for assisting daily management and achieve the heritage's preservation and disaster prevention goal.

Keywords: *Heritage, Disaster risk assessment, Protection, Preservation, Taiwan*

1. Disaster risk assessment procedure

Disaster risk assessment procedure can be divided into five stages: Risk Identification, Risk Analysis, Disaster Scenario, Risk Evaluation and Prioritization for Planning. The first steps for disaster risk assessment of historic buildings are risk identification and documentation. It is important to consider parameters such as the historic building’s surrounding environment, significant historic feature, use and management when assessing the risks of historic buildings. Assessing these parameters is necessary for determining all possible risks applicable to a historic building, the possible damages on its

cultural and historic value and threat to occupant safety. Disaster risk assessment is effective in both estimating and quantifying a historic building's current risk level and providing countermeasures for risk improvement. The process of disaster risk assessment for historic buildings is shown in Figure 1.

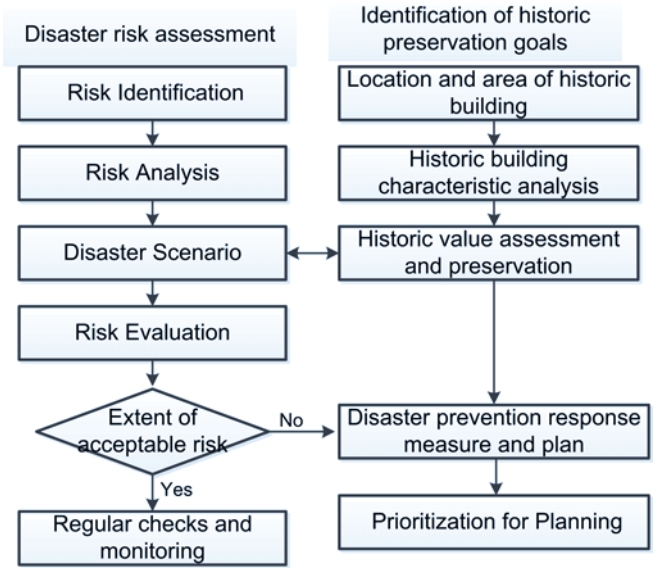

Figure 1. Conceptual process of disaster risk assessment for historic buildings

(1) Risk Identification

The key survey items in fire risk identification for historic buildings include: environmental risks, use and management risks, risk of damaging of building and cultural relics, and evacuation risks.

a) Environmental risks

Key items in environmental risk survey and identification include characteristics and conditions of a historic building's surrounding road and traffic system, adjacent building conditions, and neighboring land use. These items are all important in terms of the spread of disaster damage, rescue, and evacuation.

b) Use and management risks

Use and management risks include the type of adaptive reuse, existing occupancy and current management system.

c) Risk of damaging historic building and cultural relics

Important key factors in identifying the risks of damaging a historic building and its culture relics within include building size, building construction, disaster resistant features and vulnerability to disasters.

d) Evacuation risks

When identifying evacuation risks for a historic building, it is important to make sure that two-way evacuation is possible and that all evacuation routes remain clear at all times.

(2) Risk Analysis

The preliminary disaster vulnerabilities and protection targets can be identified based on consolidating both the current and potential risks to both the historic building and its culture relics.

The disaster prevention characteristics (in fire, earthquake and flood) for the general types of historic buildings in Taiwan consolidated in this study are shown in Table 1.

Table 1. Disaster risk characteristics for historic buildings

Item		Parameter	High Risk	Moderate Risk	Low Risk
Fire	Use and Occupancy	Occupant density (person/㎡)	≥ 1	0.3~1	≤ 0.3
		Fire load (MJ/㎡)	≥ 720	240~720	≤ 240
		Fire incidence based on occupancy	Residential	Factory/Storage	Other
	Disaster Prevention/ Reduction Plan	Daily maintenance and management	No designated manager	Either by designated manager or entrust to other agency	Designated management organization
		Disaster detection and prevention	No designated manager	Day time only	24-hour surveillance
		Emergency response	No designated manager	Designated fire prevention manager	Designated fire prevention manager and fire protection group
		Salvage and protection of cultural relic	No planned salvage measures	Include salvage measures only	Include both salvage and protection measures
	Construction	Structural members (column, beam, wall)	Non-fireproof	Quasi-fireproof	Fireproof
		Roofing, roof trusses, ceiling	Non-fireproof	Quasi-fireproof	Fireproof
		Non-fireproof: wooden construction / Quasi-fireproof: brick construction Fireproof: reinforced concrete (RC), steel construction			
	Surrounding Environment	Road width	≤ 4M	≥ 6M	≥ 11M
		Use of adjacent buildings	Residential	Factory/Storage	Other
		Construction type of adjacent buildings	Non-fireproof	Quasi-fireproof	Fireproof
Earthquake	Surrounding Environment	Architecture relationship to adjacent buildings	Danger of collision with adjacent buildings during earthquake	Danger of adjacent buildings collapsing during earthquake	No adjacent buildings
		Regional characteristics	Have suffered severe earthquake damage	Have suffered earthquake damage	No previous earthquake damage
			Neighboring live fault zone (within 500m)	Neighboring live fault zone (within 5000m)	No fault line within 5000m
		Land subsidence	Obvious land subsidence	Slight land subsidence	No land subsidence
	Construction	Size	Single floor area ≥ 500m^2	Single floor area between 250-500m^2	Single floor area ≤ 250 m^2
			Building height ≥ 9m	Building height between 6m-9m	Building height ≤ 6m
			Plan and vertical irregularity	Vertical irregularity Plan regularity	Plan and vertical regularity
		Construction	Brick	Reinforced brick, RC	Wooden, steel
	Preservation Condition	Current building condition	More than half of the main structure has been damaged	A portion of the main structure has been damaged	Main structure in good condition
		Structure deformation	Significantly deformed or tilted	Slightly deformed or tilted	Normal
		Repair records	Never been repaired	Repaired over 15 years ago	Repaired less than 15 years ago
	Disaster Prevention/ Reduction Plan	Reinforcement of culture relic	None	Relics are reinforced	Relics are reinforced and can be salvaged quickly
		Maintenance and management	No inspection of seismic items	Seismic items are inspected	Seismic items are inspected and documented

		Disaster prevention plan	No earthquake prevention plan	Self-drafted earthquake prevention plan	Earthquake prevention plan is drafted with help from design team
Flood	Surrounding Environment	Risk of flooding	Located in a high flood risk area (single-day rainfall of 600mm)	Located in a high flood risk area (single-day rainfall of 450mm)	Located outside of flood risk region
		Disaster history	Have suffered severe damage due to flood.	Have suffered damage due to flood.	No previous flood damage.
		Surrounding terrain	The surrounding roads are at a higher elevation than the historic building.	The historic building and surrounding roads are at similar elevation.	The historic building is located at an elevation higher than surrounding roads.
			Ex: Environment suffers obvious indirect flood damage such as landslides, tilted trees and falling of suspended objects.	Ex: Parts of the environment suffers from indirect damage.	Suffers no obvious indirect damage
	Construction and Current Condition	Construction	Wooden	Brick	RC, steel
		Current condition	Roof and wall are seriously damaged causing leaks	Roof and wall partially damaged, local water seepage	In good condition
		Repair record	Never been repaired	Repaired over 15 years ago	Repaired less than 15 years ago
	Disaster Prevention/ Reduction Plan	Weather information	Unmonitored	Monitored by staff	Monitored by designated person on site
		Maintenance and management	No designated person assigned to monitor area drainage condition	Designated person for monitoring and reporting area drainage condition	Designated person for monitoring and reporting drainage condition and drainage system is cleaned regularly
		Disaster prevention plan	No flood prevention plan	Self-drafted flood prevention plan	Flood prevention plan is drafted with help from design team
		Disaster reduction measures	No drainage system and flood control	Have site drainage system	Have drainage system and flood control
		Salvage and protection of cultural relic	No planned salvage measures	Include salvage measures only	Include both salvage and protection measures

(3) Disaster Scenario

Possible disaster scenarios can be established based on risk assessment results. Further analysis on disaster reduction measures and future improvement plans can be carried out based on the selected disaster scenarios.

(4) Risk Evaluation

Site survey, risk assessment and selection of disaster scenarios allow the identification of high risk areas within a historic building. The assessment results will reflect the areas that need improvement and serves as a basis for evaluating the historic building's disaster prevention response plan in the future. The disaster risk evaluation parameters for fire, earthquake and flood are displayed in Table 2.

Table 2. Disaster risk parameters for historic buildings (fire, earthquake and flood)

Type of Risk	Evaluation Parameter	Sub-parameter
Fire	Occupancy Risk	• Fire and electricity • Number of occupants • Occupancy classification
	Environmental Risk	• Risk of fire spread from outside • Road/transportation system
	Risks to damaging historic fabric	• Construction material • Vulnerability of culture relics • Culture value
	Evacuation Risk	• Evacuation routes
	Fire Prevention Measures	• Fire prevention (security and management) • Fire detection and report • Fire protection equipment • Evacuation equipment • Fire spread suppression system
	Disaster Prevention Management Checks	• Implementation of disaster prevention plan • Fire and electricity safety •Management of combustible/arson control • Evacuation safety • Management of culture relics
Earthquake	Regional Environment	• Earthquake zone •Disaster history •Live fault line •Surrounding terrain •Relation to adjacent buildings •Road system
	Building Construction	•Building height •Ratio of building height to width •Building shape •Building construction
	Current building condition	• Damages to main structure members (rotting, pest) •Structural deformation • Structure repair documentation • Changes or additions to building construction and mass
	Disaster Prevention Management Checks	• Management system • Daily maintenance and management • Fire prevention management • Disaster reduction management
Flood	Regional Environment	• Flood risk • Disaster history • Surrounding terrain- elevation of historic property • Surrounding terrain- indirect damage due to flood • Surrounding road system
	Current building condition	• Construction •Current condition- structure members • Current condition- roof, wall • Structure repair documentation
	Disaster Prevention Management Checks	• Management system • Daily maintenance and management • Fire prevention management • Disaster reduction management

(5) Prioritization for Planning

Disaster prevention measures and plans written based on the risk assessment results should establish three types of goals: short-term, medium-term, and long-term goals. The key items in disaster response plan include increasing disaster awareness, improving disaster coping ability, and strengthening preservation of both the building and its culture relics.

2. Case study- Taipei City Designated Heritage, Jinmei Jiying Temple

Jinmei Jiying Temple was constructed in 1860. Its layout is typical of mid-size Taiwanese temples. Although the temple did undergo several repair constructions, it was able to retain both its original architecture style and its significant culture contents. Jinmei Jiying Temple is located within the famous Jinmei Tourist Night Market in Taipei. The consumer activity in this area is very active: it is used for night market during the night and morning market during the day. While the large number of people to this area is beneficial to the economic prosperity in this region, it also result in a higher

level of risk.

Figure 2. Jinmei Jiying Temple

(1) Case study- fire risk assessment

a) Environmental Risk

Based on the current exit control and human habit (tendency to enter and exit from same opening), the majority of people will try to exit from the main opening and will result in bottleneck effects between the temple and Jinmei Street.

During morning and night market operation hours, Jinmei Street is open to pedestrian only. If a fire event were to occur during this time, the firefighters will be forced to parked at Jingwen Street and travel to the fire scene on foot. At the same time, Jingwen Street is likely to be crowded due to rush hour traffic causing further delay.

b) Risk analysis on current building conditions of Jinmei Jinying Temple's adjacent buildings

Jinmei Jinying Temple is located in a high fire risk area with numerous vendor stands that uses low fire resistant construction, open flame for cooking and contains a large amount of combustibles as shown in Figure 3.

A. Low fire resistant construction: Corrugated roof, plastic scaffolding, and brick-wooden construction that are low in fire resistance are common in this neighborhood. If a fire outbreak were to occur, fire would spread rapidly through this area.

B. Food stands that uses open flame: Food stands that sells noodle, snack, barbecue and fast food are high in fire risk due to their use of cooking equipment such as gas burners

C. Combustible vendor shops: clothing stores, grocery stands, leather shops all contains a large amount of combustibles that will aid fire spread in the event of a fire outbreak.

(2) Risk in damaging significant historic features, contents and evacuation

The secondary exits are locked due to security and management, which reduces evacuation route to only one direction. The secondary evacuation passageway and exit widths are narrow (approximately 1m), thus bottleneck effect is likely to occur during festival events when large of

crowds gather at the temple. It will be difficult to salvage culture relics within the temple with the secondary exit locked. With only one exit, the rescue operations such as salvaging of significant objects, firefighting and evacuation will be forced to compete with each other.

Figure 3. Risk map of adjacent buildings and current photos of Jinmei Jiying Temple

(3) Disaster Scenario

Disaster scenarios can be selected based on risk assessment results to speculate the possible hazards that are applicable to a historic building. Analyses using established disaster scenarios can help determine the most suitable disaster prevention and reduction measures for the target historic building. In terms of fire scenarios, it is best to select the worst-case scenario. For the case of Jinmei Jiying Temple, the worst-case scenario is a night time fire that results from either festival activities or a large scale earthquake.

3. Conclusion

(1) Application of disaster risk assessment method for historic buildings

The disaster risk assessment method formulated in this study is a simple disaster prevention safety assessment that can be used for selecting disaster prevention measures and risk reduction methods.

This assessment method is based on evaluation and inspection of disaster prevention characteristics, disaster risk factors and the building's management measures. Historic buildings evaluated with high existing risks should consult with disaster prevention experts and relevant government authorities as soon as possible for further assessment and formulation of short-term, medium, and long-term risk reduction measures targeting the building's high risk features.

(2) Promotion of regional disaster prevention plan

Historic buildings in Taiwan are often faced with management problems due to a lack of manpower and resources; therefore, it is important for the local agencies and governmental departments associated with the historic buildings to assist in terms of both providing the resources needed and educating the local residents about the importance of historic preservation. It is important to emphasize the cultural value of historic buildings and the economic benefit of historic preservation through tourism through education and promotion of historic preservation in the local communities.

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